POSSE TECHNOTES

The Application on the Program of Ship Salvage Engineering (POSSE)
by U.S. Navy Salvage Engineers
Volume 1, No. 1 / Summer 1999

SUPSALV Sends

In the fall of 1997, the first edition of "POSSE Technotes" was distributed by NAVSEA 00C to all POSSE users, as well as Engineering Duty Diving and Salvage Officers, and other interested parties. The original intent was merely to provide basic overview and lessons learned for real POSSE applications from actual salvage engineering evaluations for those POSSE users (or future users) who might benefit. Distribution of "POSSE Technotes" continued on a case-by-case basis, as operations and POSSE analyses were completed and documented.

This summer, NAVSEA 00C begins publication of "POSSE Technotes" as a formatted newsletter. Much like NAVSEA 00C's "Faceplate" and "Skimmer" newsletters, "POSSE Technotes" will be published periodically (approximately semi-annually) and posted on the NAVSEA 00C website, available for download as Adobe Acrobat files.

POSSE has historically been used by NAVSEA 00C in support of Navy or U. S. Coast Guard (commercial) ship salvage operations. Thus, most of the previous editions of "POSSE Technotes" have been written by NAVSEA 00C salvage engineers. However, POSSE has undergone many important improvements over the last several years, includ-

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NAVSEA Supports Salvage of M/V Concorde Spirit

At approximately 0830 on 23 October 1998, the 950 feet long coal ship M/V CONCORDE SPIRIT lost all power while transiting the narrow channel outbound near Hampton, VA. The ship subsequently ran hard aground approximately 1 mile east of Old Point Comfort. The ship was fully laden with approximately 110,000

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SUPSALV Sends *(Continued from page 1)*
ing capabilities to evaluate effects of multiple grounding points and time-phased tidal variations and liquid transfers. These improvements should make POSSE more generally applicable to a broader range of ship stability, buoyancy and strength applications, including drydockings and shipboard liquid transfers. POSSE users are encouraged to consider and utilize POSSE for these applications at shipyards and other industrial activities, in addition to more traditional ship salvage applications. I want to solicit articles written for "POSSE Technotes" about these applications and share your experiences we all may benefit from lessons learned in the field. Also, these applications might provide excellent topics for Engineering Duty Qualification Program papers.

Any POSSE user interested in authoring an article regarding a completed POSSE analysis for "POSSE Technotes", or obtaining potential EDQP topics in this area is strongly urged to contact LCDR Jeff Stettler (NAVSEA 00C20) at (703)607-2758 or e-mail: "stettlerjw@navsea.navy.mil".

metric tons of coal. Initial assessment of the stranding conditions using POSSE RAPID indicated that the ship would be approximately 20,000 metric tons aground at the highest expected tide.

Over the next 36 hours, several unsuccessful attempts were made to free the stranded ship. During this period, approximately 14,500 MT of ballast water was removed in attempt to lighten the ship for retraction. At 0130 on 25 October, the USCG Marine Safety Office (Captain of the Port) Hampton Roads, VA requested that the U.S. Navy Supervisor of Salvage (NAVSEA 00C) provide salvage technical assistance for salvage of the stranded ship. NAVSEA 00C dispatched a Salvage Engineer to perform an initial assessment of the stranding and advise the USCG Captain of the Port on subsequent salvage action to be taken by the owner. The owner hired the salvage firm SMIT Americas to salvage the stranded ship.

It was determined that systematic lightering (removal) of coal would be required to refloat the ship. On 27 and 28 October, approximately 9500 metric tons of coal were lightered to a barge using a floating clamshell crane. As the coal was lightered, 14,000 metric tons of ballast water were brought aboard to maintain the ship's grounding during flood and ebb tidal currents. With final deballasting of approximately 10,000 metric tons of seawater during the flood of the tide, the ship floated free at 1120 on 28 October, approximately 3 hours before high tide. The ship was taken to anchorage for inspection and re-introduction of the lightered coal, prior to setting sail for South Africa as originally planned.

General Information

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Casualty Type: *Stranding*
Casualty Date: *23 Oct 1998*
Location: *Hampton Roads, VA*
Ship Name/Classs: *M/V Concorde Spirit*
Ship Type: *Coal Carrier*
Owner: *Japanese*
Flag: *Philippines*

Ship Characteristics			
LBP:	280 m	**Cb:**	0.827
Beam:	46 m	**Cw:**	0.916
Depth:	24.8 m	**Cp:**	0.85
Service Speed:	14 kts	**Cm:**	0.973
Disp. (Full Load):	204,693 MTons	**MT1:**	2,492 m-MT/cm
Draft (Full Load):	14m	**TP1:**	121 MT/cm

NAVSEA 00C Salvage Engineers utilized the Navy's Program of Ship Salvage Engineering (POSSE) to predict the ship's ground reaction, longitudinal bending and shear stresses, and afloat stability and drafts, ensuring that the salvage operation could be completed effectively and safely.

POSSE Application

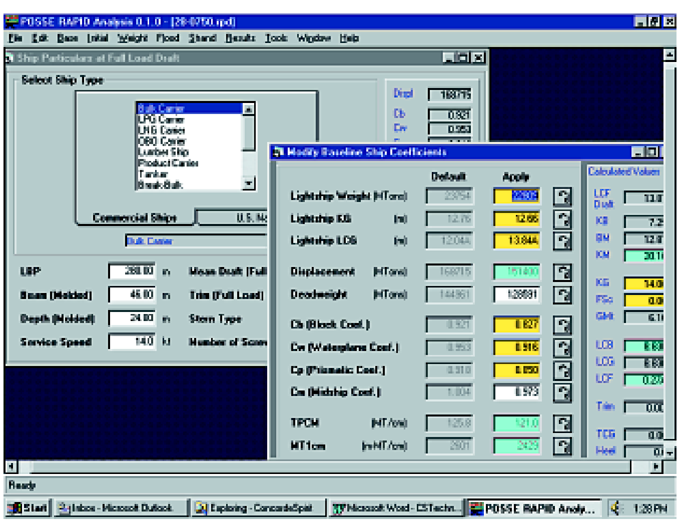
RAPID Modeling and Analysis:

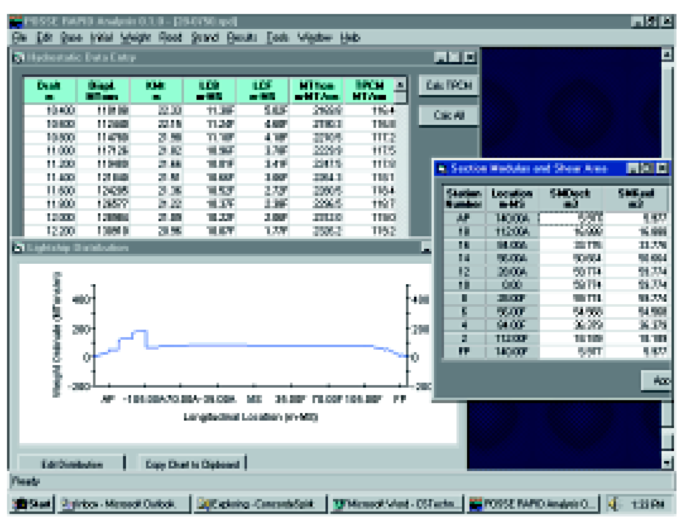
Because of the short time available, and lack of a pre-existing DETAILED hull model, all modeling and analysis work in this case was performed in the RAPID mode of POSSE. Also, as the ship was obviously aground over all of its length and there was little trim, addition of hydrostatic table data directly into RAPID would provide sufficiently accurate results for this salvage case. As the Salvage Engineers had access to the nearly completed Beta (test) version of the Windows version of POSSE RAPID, illustration of this analysis is given using this Windows version.

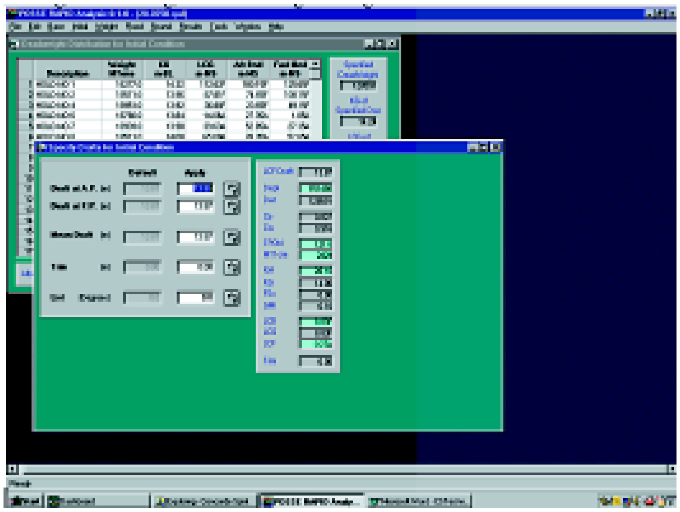
When initially informed of the stranding on the afternoon of 23 October, basic ship information (type, length, beam, depth) and draft readings (before and after stranding) were used to provide an initial approximation of ground reaction using the (default) parametrics in POSSE RAPID. The "base" ship parametric model was developed as a "bulk carrier", with LBP, Beam, Depth and Service Speed (initially estimated to be 15 knots) entered. Pre-underway ("initial" condition) drafts were reported to be 14m fwd & aft. Drafts at the time of the first survey ("stranded" condition) at 1515 on 23 October were reported to be 11.25m fwd and 12.55m aft. With these drafts, POSSE RAPID parametrics estimated a total ground reaction of 25,000 metric tons. For the next high tide, ground reaction was estimated to be 20,000 metric tons. It was obvious that lightering of cargo (coal) would be required to refloat theship.

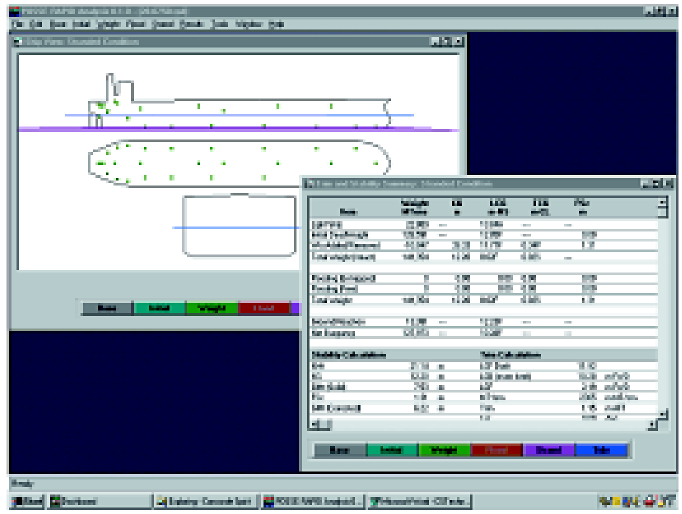
Once onboard the ship, a limited amount of technical information regarding the stranded ship was obtained. This information included Trim and Stability (T&S) Book, General Arrangement Drawing, "loading computer" printouts, and tank sounding and cargo manifest data. The "base" RAPID model was developed by creating a ship model for a bulk carrier with the principle characteristics of the M/V Concorde Spirit. The actual lightship weight and centers (documented in the T&S Book) were entered. The actual hydrostatic tables (documented in the T&S Book) were entered in tabular format. This (new) feature allowing entry of hydrostatic tables provides RAPID with the ability to use actual hydrostatic properties (TP1, MT1, KM, etc.) for all calculations (vice parametrically derived values), making RAPID even more accurate than traditional hand or spreadsheet calculations, where hydrostatic properties are taken by hand from Curves of Form. Also, in this case, stranded trim was less than 1.5 meters (less than 0.2% of ship's length), so utilization of hydrostatic tables would be quite accurate. The lightship weight distribution for structural strength calculations was generated using the "Develop Lightship Weight Distribution" option, developing a ship-specific lightship weight distribution, modifying it to match the ship's actual structure (based on the General Arrangement Drawing), and the actual lightship weight and centers. Hull structural stength properties were estimated using typical allowables (per ABS/IACS rules). This was necessary because scantling drawings or specific section properties (section modulii, moments of intertia, shear areas) were unavailable. However, assuming that section properties were equal to (minimum) allowables was believed to be conservative, in that sections are typically designed and built in excess of (minimum) allowables.

In order to develop the salvage load cases for the ship in its stranded condition and during phases of lightering, deballasting and refloating, the "initial" case was defined using reported underway drafts and deadweight distribution from the ship's manifest and tanks sounding logs. Initial deadweight loads (weight, centers, and forward/aft bounds) were entered, and a small correction was applied to match underway drafts. The stranded condition at each desired tidal height was developed by applying the lightering, ballasting, deballasting, and other weight changes. For the stranded conditions at each tidal height (low and high tides), stranded drafts were entered, with drafts predicted for future tides based on tide curves and a series of draft readings taken through several tidal cycles during the first several days of the operation. Ground reaction and bending stresses were predicted for each tidal height. Refloated drafts were predicted for the afloat condition, with the lightering, ballasting, deballasting, and other weight changes included. Final refloated drafts were predicted within 0.2 m of actuals.









Special Considerations / Lessons Learned

This salvage engineering case was a very straight forward application of salvage engineering principles. It also proved to be an excellent application for POSSE RAPID. With the limited time available and the limited amount of technical documentation available, it was not feasible to develop a reasonable DETAILED POSSE model in a timely manner. However, due to recent improvements in RAPID, a capability exists to utilize hydrostatics table data directly, bypassing default parametric calculations, making RAPID a very accurate salvage engineering assessment tool. Additionally, lightship weight and centers could be input from available documentation, and lightship weight distribution could be developed for strength calculations, allowing suitable evaluation of longitudinal bending stresses during all phases of the salvage operation.

USS RADFORD Collision Initial Damage Assessment and Drydocking Evaluation

On 5 February 1999, while conducting exercises off Hampton Roads, VA, the USS Arthur W. Radford was involved in a collision at sea with a Saudi Arabian container vessel. The Saudi vessel's stem and bulbous bow penetrated the starboard side of the Radford, centered near frame 69 (approximately at the location of the forward 5" gun mount). As a result of the collision, the Radford experienced significant structural damage and flooding from frames 58 through 94, with additional flooding within sonar equipment spaces between frames 29 and 58. Post damage inspections indicated that flooding was complete (free-flooded to the waterline). Structural damage from the stem of the Saudi vessel consisted of complete penetration of the side shell and main deck from the 1st platform deck (24' above baseline) on the side shell to the ship's centerline on the strength (01) deck, with damage ex-

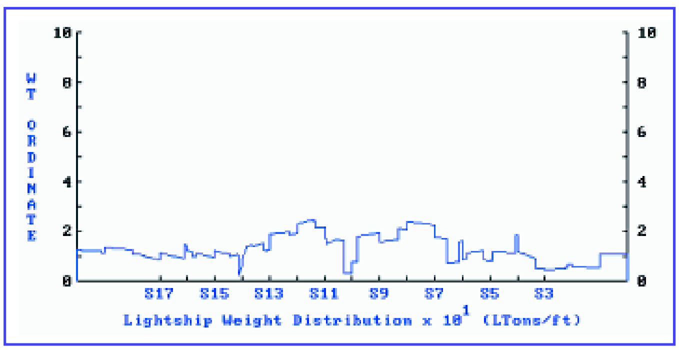
tending mainly from frames 52 through 84. Additional structural damage below the waterline from the bulbous bow of the Saudi vessel consisted of complete penetration of the side and bottom shell from the 2nd platform deck (15' above baseline) to the center vertical keel at the baseline, with damage extending mainly from frames 64 through 82. Outside these primary penetration areas, there was significant buckling of decks and tripping of stiffeners caused by the transverse force of the collision. Thus, many of the structural members outside the primary penetration area provided reduced effective strength to the hull girder.

Norfolk Naval Shipyard was tasked with stabilizing the vessel and drydocking for initial assessment and planning for eventual repair/replacement of the bow of the ship. Initial assessment of the collision damage to the ship was provided utilizing POSSE. Additionally, POSSE was utilized to provide assistance in the development of a weight removal and deballasting plan for preparing the ship for drydocking on 25 February. POSSE was also utilized to provide an evaluation of the drydock block bearing loads and ship's structural strength during and following the drydocking process. Finally, POSSE was utilized to provide an initial assessment of stability and structural strength of a potential (proposed) refloating of the ship with the bow section removed (forward of frame 94). The ship was drydocked at Norfolk Naval Shipyard Drydock #3 on 25 February.

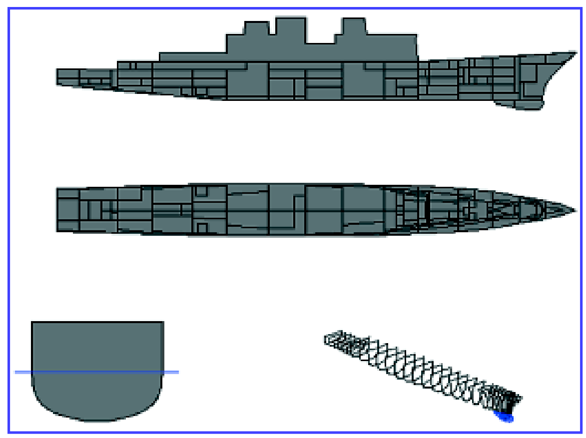
POSSE Application

DETAILED Modeling:

The ship's initial (undamaged) condition was developed utilizing an existing SUPSALV electronic POSSE model for the DD 963 class (with VLS). This electronic POSSE model included full entry of hull and all compartment offsets into the 3-dimensional electronic model, in addition to representation of a number of ship structural sections for longitudinal strength calculations. Lightship weights (weights, centers, and longitudinal weight distribution) were based on class data and modified to match DD 968. The initial (intact) load case was developed based upon detailed weight logs provided by Norfolk Naval Shipyard, matched to the ship's underway drafts.

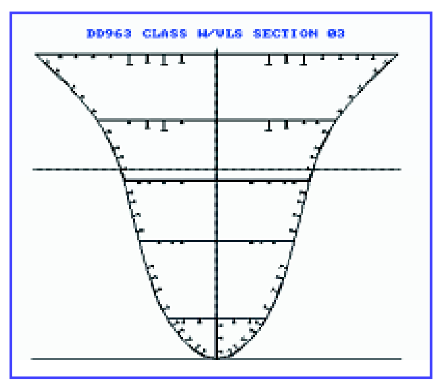


Initial Lightship weight distribution



Hull stations/offsets and compartmentation

Ship Characteristics			
LBP:	529 ft	**Cb:**	0.51
Beam:	55.1 ft	**Cw:**	0.75
Depth:	35 ft (main deck)	**Cp:**	0.61
Service Speed:	30+ kts	**Cm:**	0.84
Disp. (Full Load):	9,375 LTons	**MT1:**	1,615 ft-Lton/in
Draft (Full Load):	21.88 ft	**TP1:**	52.2 ft-Lton/in



Intact longitudinal structure at frame 69

General Information

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Ship Name/Class: *USS Arthur W. Radford (DD968) DD963wVLS*
Casualty Type: *Collision* Casualty Date: *5 Feb 1999*
Location: *Norfolk, VA* Customer: *Norfolk NSY*
Ship Type: *Destroyer* Owner: *SURFLANT*
Flag: *U.S.*

DETAILED Analysis:
1. Collision Damage Assessment:

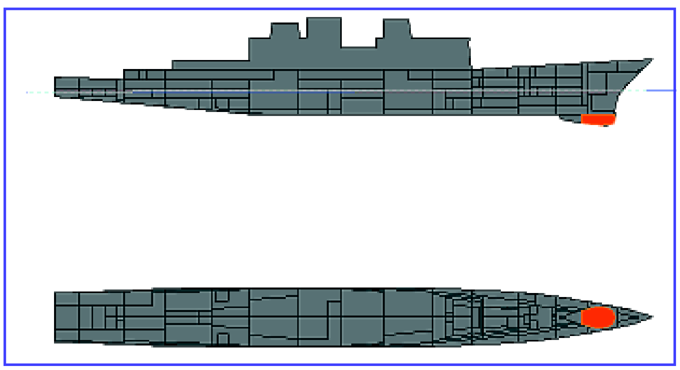
As a result of the collision, the Radford experienced significant structural damage and flooding from frames 58 through 94, with additional flooding within sonar equipment spaces between frames 29 and 58. Post-damage inspections indicated that flooding was complete (free-flooded to the waterline).

POSSE was used to calculate trim, stability, and residual strength of the Radford in the afloat damaged condition. Damaged drafts were calculated to be 26.4' forward and 20.0' aft (trim of 6.39' by the bow). Actual drafts on 2/7/99 were 26' 5" (26.42') forward and 20' 2" (20.15') aft. The ship maintained sufficient transverse stability following damage (as indicated by the righting arm curve and a GM of 3.16'). Subsequent evaluation of the righting arm curve indicated that the stability met underway wind heel and roll criteria of DDS079-1.

Damaged Hull Girder Strength Issues:

Structural damage from the stem of the Saudi vessel consisted of complete penetration of the side shell and main deck from the 1st platform deck (24' above baseline) on the side shell to the ship's centerline on the strength (01) deck, with damage extending mainly from frames 52 through 84. Additional structural damage from the bulbous bow of the Saudi vessel consisted of complete penetration of the side and bottom shell from the 2nd platform deck (15' above baseline) to the center vertical keel at the baseline, with damage extending mainly from frames 64 through 82. Outside these primary penetration areas, there was significant buckling of decks and tripping of stiffeners caused by the transverse force of the collision. Thus, many of the structural members outside the primary penetration area provided reduced effective strength to the hull girder.

With the significant structural damage experienced by the RADFORD during the collision, the ship's hull girder strength was seriously impaired in way of the damaged section. POSSE was utilized to provide evaluation of the residual hull girder strength for the damaged condition. Based upon structural surveys, damage was applied to structural elements in the damaged section for purposes of calculation of section modulii and shear areas. For structural elements deemed completely ineffective, the elements were removed from section modulii and shear area calculations. For structural elements deemed only partially effective (i.e. due to partial buckling of plating and/or tripping of stiffeners), the



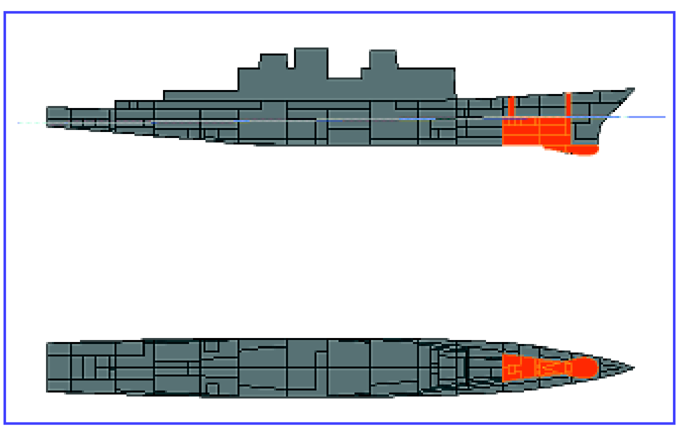
Initial condition with sonar dome "flooded"

Item	Weight LT	VCG ft	LCG ft-FP	TCG ft-CL	FSMom ft-LT
Light Ship	6,798.9	27.04	276.27A	0.00	---
Constant	0.0	0.00	264.50A	0.00	---
JP-5	67.6	10.63	408.62A	0.13S	0
Fuel Oil	1,481.1	8.37	278.22A	0.37P	0
Fresh Water	44.2	11.69	259.35A	6.73P	0
SW Ballast	178.7	7.33	312.05A	4.49S	0
Misc.	16.9	2.68	268.25A	0.20S	0
Constant	22.6	29.42	248.67A	0.00	0
Misc. Weights	591.7	28.97	280.41A	0.05S	0
Displacement	9,201.8	23.54	278.35A	0.00S	0

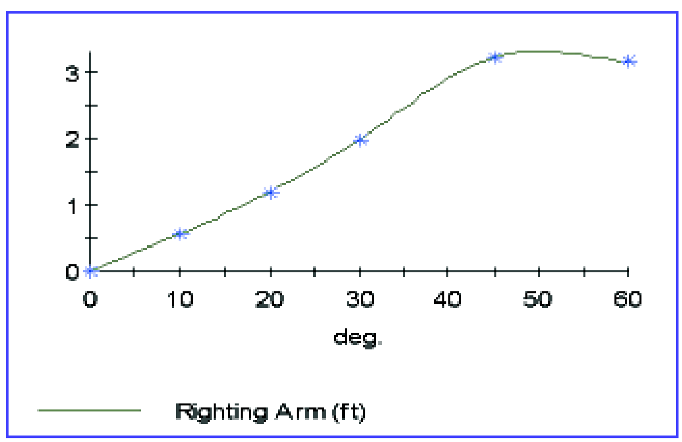
Stability Calculation			Trim Calculation		
KMt	26.20	ft	LCF Draft	21.85	ft
VCG	23.54	ft	LCB (even keel)	277.39A	ft-FP
GMt (Solid)	2.65	ft	LCF	307.01A	ft-FP
FSc	0.00	ft	MT1in	1,614	ft-LT
GMt (Corrected)	2.65	ft	Trim	0.46	ft-A
			List	0.0	deg

Drafts			Strength Calculations		
Draft at F.P.	21.58	ft	Shear	0.0	LT 0.% Allowable
Draft at M.S.	21.81	ft	Bending Moment	0	LT 0.% Allowable
Draft at A.P.	22.04	ft			

Initial (intact) loading condition



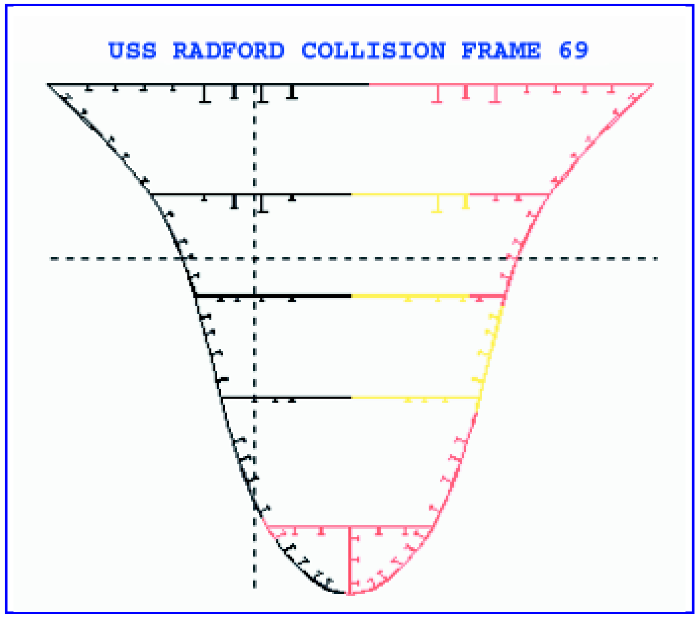
Initial damaged condition with free-flooding of the damaged compartments



elements' effectiveness was reduced by applying a "corrosion" factor, reducing the contribution of the elements to the section modulii and shear area calculations. The damaged section (e.g. at frame 69) was calculated to have lost up to 60% of it's original section modulii (to both keel and deck) and approximately 35% of it's shear area about it's horizontal neutral axis (i.e. for vertical bending and shear).

POSSE calculated bending and shear stresses in way of the damaged section. Maximum stresses were under 30 ksi compression at the keel and 15 ksi tension at the strength (01) deck for bending, and under 5 ksi for shear for all potential damaged load cases envisioned. As the hull structure is primarily HTS (High Tensile Strength) steel, with a nominal yield strength of approximately 51 ksi, there was a factor of safety of less than 1.8 to yield in the extreme elements of the keel (compressive yielding). It should be noted that POSSE utilizes prismatic beam theory in evaluation of hull girder stresses. Thus, bending stresses are assumed to vary linearly across the section, with maximums at the extreme elements (keel and deck). Actual stresses do not vary linearly due to non-linear phenomenon of shear flow and shear lag. However, for purposes of evaluating risk of hull girder failure, experience has shown that this approach is reasonably accurate, provided non-linearities are considered and suitable factors of safety to hull girder failure are provided for.

In order to increase the factor of safety to yield in the damaged structural section, additional stiffening members were fabricated and welded to the hull. Three large (36" T) beams were welded to the strength (01) deck, and one large (36" T) beam was welded to the starboard side shell at the main deck level. These stiffening members had the net effect of increasing the section modulii of the damaged section by approximately 10-15% thus reducing maximum bending stresses by 9-14% in the damaged section.



Damaged structural section at frame 69 (black = fully effective, red = ineffective, yellow = partially effective)

SM COMPARISON TABLE

	Intact	*Damaged*	*% Loss*
About Horizontal Neutral Axis			
Area:	1403.73 in2	77.23	44.6%
Ixx:	3.47E+05 in2-ft2	1.50E+05	56.9%
SM-Upper Flg:	20166.74 in2-ft	9611.54	52.3%
Y Upper:	17.22ft	15.57	
SM-Lower Flg:	12262.32 in2-ft	4993.71	59.3%
Y Lower:	28.31 ft	29.96	
Shear Area y:	660.49	414.96	37.2%
About Vertical Neutral Axis			
Iyy:	1.65E+05 in2-ft2	49611.97	70.0%
SM-Left Flg:	7455.3 in2-ft	3279.09	56.0%
X Left:	22.17 ft	15.13	
SM-Right Flg:	7443.79 in2-ft	1696.04	77.2%
X Right:	22.21 ft	29.25	
Shear Area x:	958.11 in2	605.04	36.9%

(computed at calculated extreme fibers)

Most combatant ship structures are designed and built with sufficient stiffness such that hull girder yield is the initial or limiting mode of structural failure within the hull girder. However, with the extensive damage experienced by the RADFORD, other modes of hull girder failure may have become limiting at or near the damaged section at frame 69 and needed to be considered. For example, with unsupported stiffened panels near the keel (due to loss of adjacent supporting structure), panels may first fail by buckling, or stiffeners may first fail by tripping. This is important because those elements near the keel were under high compressive stresses.

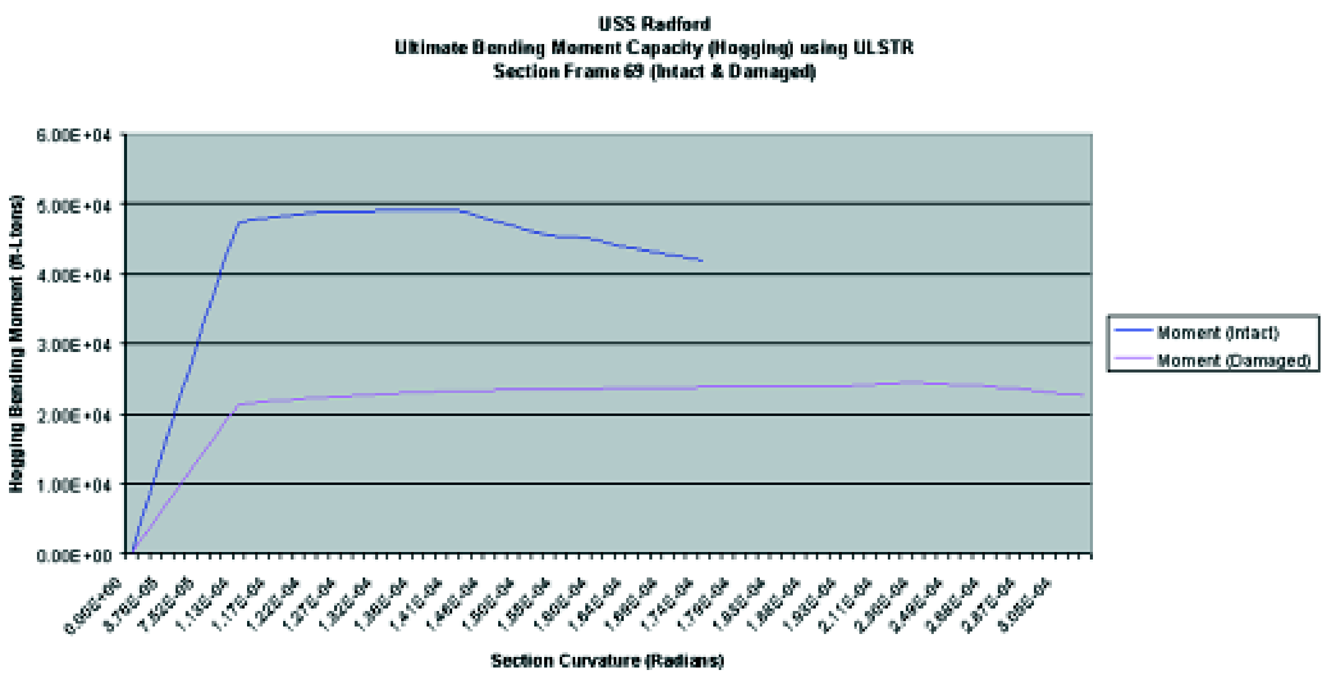
A new feature available with the Windows version of POSSE (still in Beta testing) will be a capability to evaluate hull girder ultimate strength utilizing the U.S. Navy's computer program Ultimate Strength (ULSTR) as a peripheral application (i.e. run from within POSSE). ULSTR performs a "limit state" analysis, and evaluates the ultimate hull girder strength by calculating bending moment necessary to yield, buckle or trip structural elements in sequence. Elements also shed load following initial failure, and thus adjacent elements must pick up the load shed by the failed adjacent elements. This can lead to a sequenced collapse of a hull girder, which may take place at or below bending moment levels which first cause yield in the extreme elements. ULSTR was run within POSSE for the evaluation of the ultimate bending moment capacity of the damaged section at frame 69. Results of this analysis estimated that the damaged section had lost up to 55% of it's original moment carrying capacity (with a factor of safety of less than 1.7 to hull girder collapse). Additionally, the "limit state" analysis indicated that initial failure mechanisms were associated with tripping of stiffeners and buckling of "beam-column" elements (stiffened panel elements), initiating at bending moment levels as low as 22,000 ft-Ltons. The maximum calculated vertical bending moment in any damaged load case envisioned was approximately 15,000 ft-Ltons. Thus, factor of safety to initial hull girder element compressive failure was calculated to be less than 1.5.

2. Weight Removal and Deballasting Plan for Drydocking:

In order to ballast and trim the RADFORD for entering Drydock #3 at Norfolk Naval Shipyard, a weight removal and deballasting plan was developed which maintained acceptable stability and minimized hull girder stress levels, while obtaining the desired trimming and draft goals. Maximum allowable drafts for entering Drydock #3 were established by the Shipyard at 22' 6" forward and aft, with a goal of 0" trim, but a maximum trim of 1' 0" by the stern. Trim by the bow was not desirable. These drafts would provide for required 1' of clearance over the drydock sill.

The weight removal/deballasting plan included:

- Removal of all of the nearly 300 Ltons of ordnance onboard. Much of this ordnance was located in the forward magazines, which were flooded, and was the goal of the early weight removal for reasons of ordnance safety.
- Removal of anchors and chain. Removal of weight forward of the damaged section (frame 69) was desirable in order to reduce bending moment across the damaged section, in addition to reducing trim by the bow and draft forward. The only removable weights that met this goal were the anchors and chain.
- Removal of the forward gun mount. With the gun mount dislodged as a result of the collision, it was believed to be easily removable, providing a good trimming effect.
- Removal (lightering) of fuel oil (and compensating water) from the forward compensated fuel bank. This was the only large weight that could be removed, without resorting to significant underwater work to repair the major damage to the flooded compartments. Note: Removal of fuel oil from the forward fuel bank required installation and satisfactory watertight integrity



testing of blanks on the 10" sluice lines between tanks 6-58-1/2-F and 6-94-1/2-F (port and starboard). If this could not be accomplished successfully, removal of the fuel from this forward fuel bank would not have been possible. As a backup, the alternate plan included dewatering of the sonar dome using ship's service compressed air and addition of drydock weights (pier blocks) on the fantail to even out the trim. However, the alternate would not include as much draft margin for entering drydock.

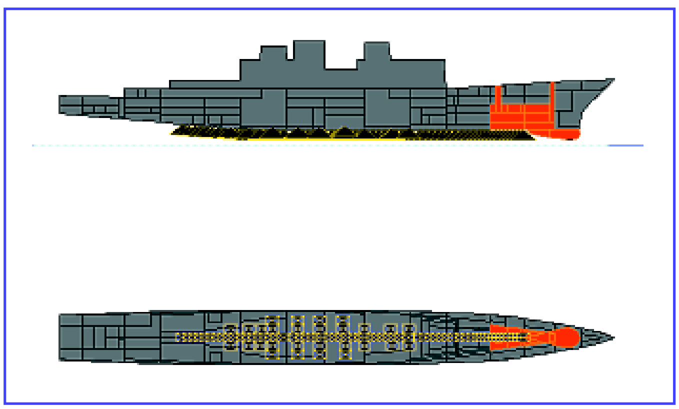
With successful lightering, it was calculated that the vessel would obtain drafts of 20.88 forward and 21.21' aft for entering drydock. Stability would remain acceptable, even as lightering of the fuel/water from the forward compensated fuel bank was accomplished prior to ordnance removal. Minimum expected GM was calculated to be 2.3 feet. The righting arm curve was evaluated to meet underway wind heel and roll stability criteria of DDS079-1. Additionally, maximum hull girder bending stresses in the damaged section would be reduced to less than 25 ksi (compression at the keel).

Following removal of ordnance, it was discovered that predicted trimming effects were not obtained. It was subsequently concluded that the ordnance weight and location information provided with the loading condition information was apparently inaccurate. However, despite this shortcoming, acceptable fore and aft drafts for entering drydock were obtained, providing a 2' clearance over the sill.

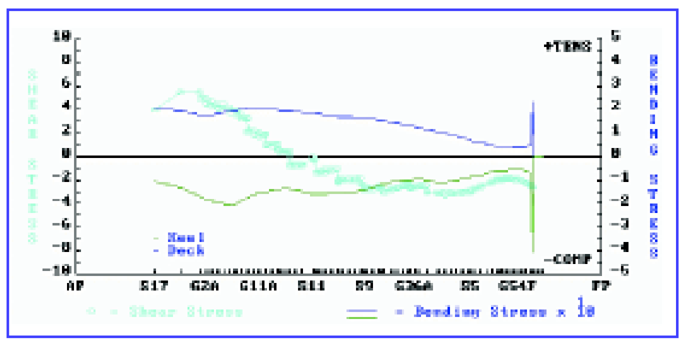
3. Initial Assessment of Drydock Block Loading and Hull Girder Bending Stresses in Drydock:

Per request of Norfolk Naval Shipyard Naval Architects, POSSE was utilized to model the USS RADFORD in drydock. The "Multiple Point Grounding" (MPG) feature in POSSE was used to model drydock blocks (keel and side blocks), and evaluate effects of pumping down the drydock on individual block loading, as well as on hull girder stresses. Note that all damaged compartments drain into the drydock as the dock is "pumped down", as they are open to "free-flood". Additionally, the sonar dome would be dewatered during or shortly following drydock dewatering.

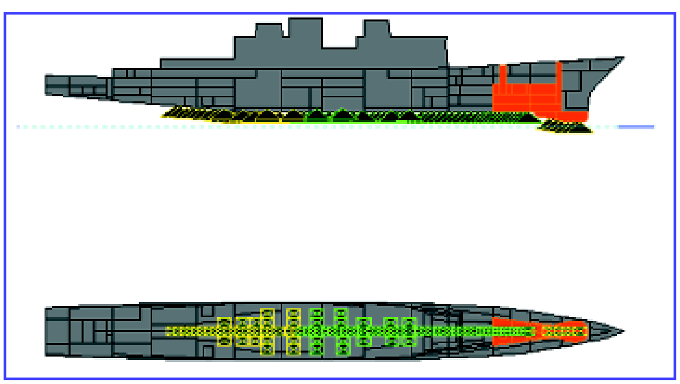
The drydock block buildup was modeled by 88 individual "grounding points", at specified locations of the individual drydock blocks. POSSE rigorously calculated reaction force on each of the individual blocks required to satisfy force equilibrium. For the initial case where the drydock is pumped down, but the sonar dome remains full, individual block loads (in Ltons) were calculated to range from 194 ltons (on the aft keel block) to 21 ltons (on the forward keel block). It should be noted that this approach assumes that the ship is represented by a rigid body, with the given shape, weight and center of gravity. Thus, the block loading distribution is calculated based upon the ship's geometry (offsets), center of gravity, and block distribution (locations). The hull was assumed NOT to deflect due to the drydocking (i.e. "hull deflection" was set to the default "no deflection of hull girder"



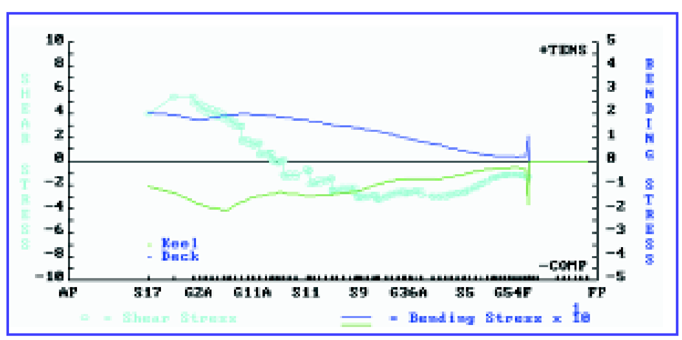
Drydock blocking modeled using POSSE's "Multiple Point Grounding" capability



Longitudinal stress distribution in drydock, sonar dome full



Drydock blocking modeled, with sonar dome blocking added



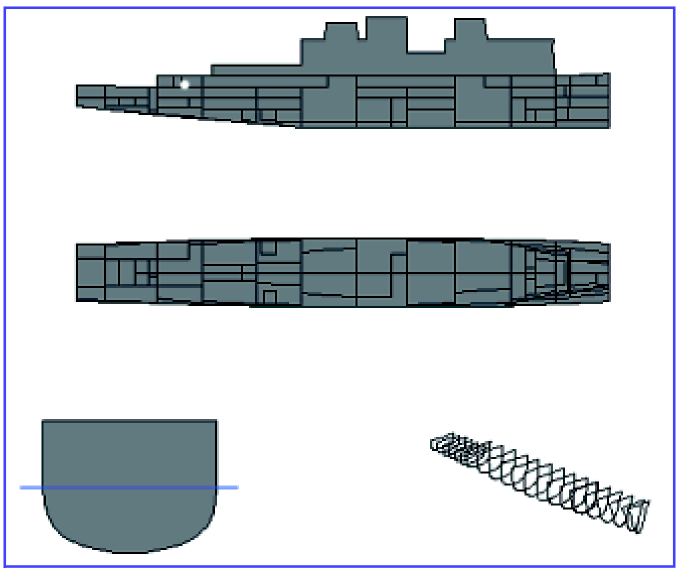
Longitudinal stress distribution in drydock, sonar dome empty and supported with blocking in the "options" menu in Salvage Response). One alternative under POSSE 2.2 is to allow POSSE to calculate hull deflections based upon hull girder structural strength and longitudinal bending moment, or "inertias". However, this approach requires a complex numerical iteration for the program to converge on a solution for both ground reaction at the 88 grounding points, plus the hull girder deflections. This multiple iteration scheme is numerically complex and does not converge easily. In fact, in this configuration, convergence could not be obtained with "hull deflection" set to "computed deflection based on hull girder inertias", unless the number of grounding points (i.e. drydock blocks) was reduced to a small number (less than 10 in this case) and the "spring stiffness" was significantly reduced to soften the force/compression curve on each block.

Predicted longitudinal bending and shear stresses are presented below. Bending stress at the damage section was expected to reach 41 ksi at the keel (compression) and 23 ksi at the strength deck (tension). The predicted bending moment at the damaged section was calculated to be approximately 24,500 ft-Ltons, which would be in excess of the ultimate bending moment capacity of the damaged section, calculated based on ULSTR analysis. This was clearly undesireable.

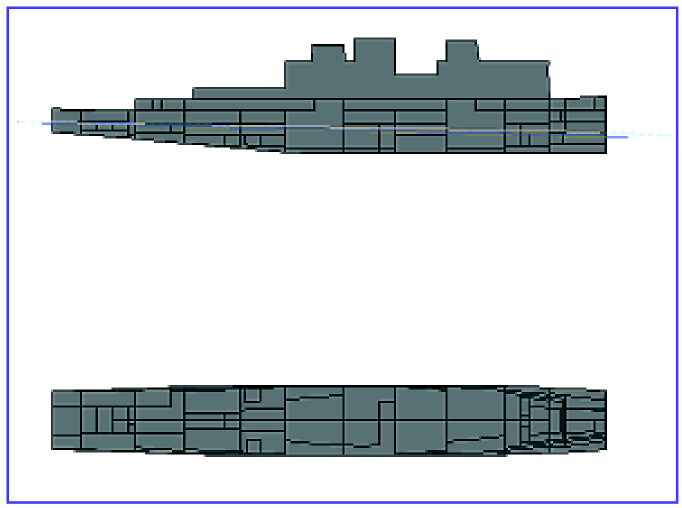
Given the undesireable stress levels and bending moment in drydock with the sonar dome full, two possible steps could be taken to reduce bending moments at this damaged section:

(1) Dewater the sonar dome prior to emptying the drydock or dewatering the sonar dome during the drydock dewatering process, but prior to the drydock becoming empty. This provides reduced bending moments at the damaged section. Bending stress at the damage section with the sonar dome dewatered were calculated to be reduced to approximately 33 ksi at the keel (compression) and 19 ksi at the strength deck (tension).

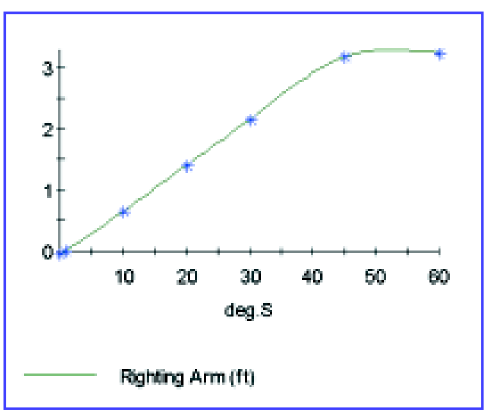
(2) Add drydock blocking under the sonar dome foundation (bellyband), thus reducing bending moments across the damaged section. In order for this to



DD968 Stern Section Hull Offsets and Compartmentation



DD968 Stern Section Afloat Condition



DD968 Stern Section Righting Arm Curve

Item	Weight LT	VCG ft	LCG ft-FP	TCG ft-CL	FSMom ft-LT
Light Ship	5,918.8	27.04	303.65A	0.00	---
Constant	0.0	0.00	264.50A	0.00	---
JP5	67.6	10.63	408.62A	0.13S	0
Fuel Oil	801.2	9.92	355.21A	1.04P	0
Fresh Water	44.0	11.69	260.45A	6.70P	0
SW Ballast	233.1	6.48	259.04A	3.85S	0
Misc.	16.9	2.68	268.25A	0.28S	0
Constant	22.6	29.42	248.67A	0.00	0
Misc. Weights	314.1	23.62	358.24A	2.04S	0
Displacement	7,418.3	24.11	310.58A	0.08S	0

Stability Calculation			Trim Calculation		
KMt	27.89	ft	LCF Draft	20.02	ft
VCG	24.11	ft	LCB (even keel)	290.70A	ft-FP
GMt (Solid)	3.78	ft	LCF	320.80A	ft-FP
FSc	0.00	ft	MT1in	1,231	ft-LT
GMt (Corrected)	3.78	ft	Trim	10.11	ft-A
			List	0.95	deg

Drafts			Strength Calculations		
Draft at F.P.	13.89	ft	Shear	271.9	LT
Draft at M.S.	18.95	ft	Bending Moment	32,592H	ft-LT
Draft at A.P.	24.00	ft			

DD968 Stern Section Afloat Draft and Displacement Data

achieve much effect on reducing bending moments and stresses, the blocking under the sonar dome would need to have sufficient height to ensure they are sufficiently loaded to reduce bending moments across the damaged section. For example, where blocks under the sonar dome are set ½" above the height contour of the sonar dome, bending stresses across the damaged section could be reduced to 18 ksi at the keel (compression) and 11 ksi at the strength deck (tension), providing an acceptable factor of safety to yield.

For the drydocking, Norfolk Naval Shipyard included drydock blocking under the bellyband of the sonar dome. This blocking was set to the sonar dome offset heights, providing sufficient loading of the blocking, since the bow/sonar dome had dropped approximately 1" due to relaxation of the structure since the collision.

4. Initial Assessment of Refloating the Ship with the Bow Section Removed:

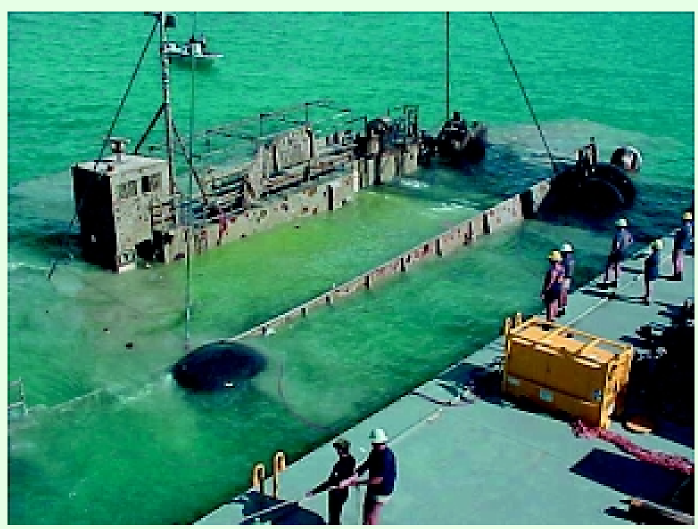
Per request of Norfolk Naval Shipyard naval architects, POSSE was utilized to model and evaluate the afloat condition of the USS Radford with the bow section (forward of frame 94) removed. This was done to determine viability of a plan to move the ship to another drydock for installation of a replacement bow section. The modified POSSE ship data files were developed by deleting hull stations and compartments forward of frame 94, and adjusting weights (lightship weight distribution and variable loads) by removing components forward of frame 94. It was assumed (for the initial evaluation) that all tankage and other variable loads remained the same as for the initial drydocking condition. In this case, the stern section should float with approximate drafts of 15.7' forward and 24.0' aft. It should be noted that this forward draft is referenced to the new "bow" of this stern section (i.e. frame 94), vice the original forward perpendicular of the DD968. Stability of this stern section in this condition would be excellent, with a predicted GM of 3.78' and large righting arms throughout a large range of stability. While this initial analysis was completed using the initial (drydocked) loading condition, it is clear that some variation of loading would be required for the ship to float at a more suitable (even) trim for undocking.

Special Considerations / Lessons Learned

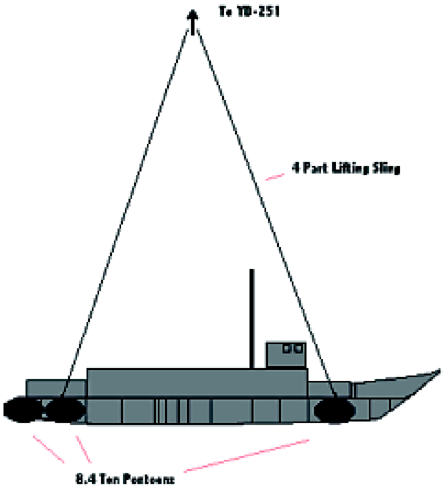
As this POSSE model was CONFIDENTIAL, conduct of the POSSE evaluation was inconvenient, although not problematic. Files required storage on a single 3.5" floppy disc (1.44 MB), and occasionally salvage case files not absolutely mandatory required deletion to make sufficient room on the single floppy disc. It should be noted that POSSE models for larger ships (e.g. aircraft carriers, amphibious vessels, etc.) could be problematic since the models will not fit on a single 1.44 MB floppy disc. It is recommended that users who anticipate use of larger CONFINDENTIAL POSSE models consider acquisition of a Zip Drive (100-200 MB), vice requiring their hard drives be made CONFIDENTIAL in an emergency.

MDSU2 Salvages YFU-83 at Roosevelt Roads, PR

On or about 21 September 1998, during Hurricane Georges, Navy YFU-83 sank at Naval Station Roosevelt Roads, Puerto Rico. The YFU had been placed in a hurricane moor to ride out the hurricane, but subsequently took on water and sank at its mooring, in approximately 34 feet of water. The YFU, which was virtually identical to an LCU (1646 class) was used to transport supplies between Puerto Rico and adjacent islands. The vessel sank without cargo, but with a full load of fuel (approximately 3,000 gallons of number 2 diesel fuel).



With all the other (high priority) hurricane recovery work occurring at NAVSTA Roosevelt Roads, salvage of the YFU was of low priority and postponed. However, environmental concerns forced early removal of the fuel held onboard the vessel. SUPSALV, using it's east coast salvage contract with DonJon Marine, removed the fuel using a vacuum extraction system obtained on the island



of Puerto Rico. Fuel was vacuum flushed from the high side tank vents, with seawater entry through the low side fuel fill system. The fuel removal effort was completed on 2 October 1998.

With the immediate environmental concerns alleviated, NAVSTA Roosevelt Roads began evaluating options for eventual salvage of the vessel. Eventually, NAVSTA Roosevelt Roads requested that Mobile Diving and Salvage Unit Two (MDSU2) salvage the vessel. The MDSU2 plan included a combination lift using NAVSTA's 100 ton YD-251, along with external buoyancy from six 8.4 lton salvage pontoons (from the ESSM base in Williamsburg, VA), and internal buoyancy provided using several air/water tight compartments. Actual salvage took place in early February 1999.

Mud suction was a factor. However, utilization of a yard tug (YTB) to horizontally shear the mud suction was successful in overcoming mud suction and facilitating lift to the surface. Once the vessel was lifted to the surface, all spaces were dewatered into a NAVSTA slop barge (SWOB).

NAVSEA 00C provided salvage engineering support for MDSU2 via technical evaluation of the salvage plan and basic salvage calculations using POSSE.

POSSE Application

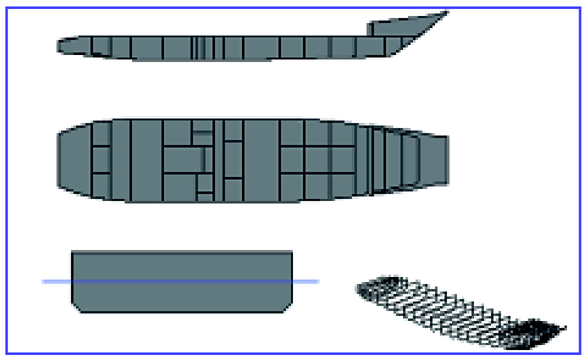
DETAILED Modeling:

The YFU-83 was actually of the same hull form and configuration as an LCU 1646 class. NAVSEA 00C had previously developed a DETAILED POSSE model for the LCU-1652, which had grounded in January 1998 on San Clemente Island, CA. This POSSE model was modified to match the estimated condition of the YFU-83.

Unfortunately, the most significant unknowns with the YFU-83 were the actual vessel weight and center of gravity. NAVSTA Roosevelt Roads had drawings of the vessel (actually, LCU-1646 class drawings), but no information was available on the vessel's weight or center of gravity. Presinking drafts were not available, which could have been used to calculate weight and center of gravity. As a result, the lightship weight and centers for the LCU-1652 were used for the YFU-83, and a "correction" was applied in attempt to estimate the small amount of variable load that may have been aboard prior to the sinking. This was considered somewhat of a "swag", as numerous "sailor-alts" had obviously taken place (i.e. installation of doubler plates, piping modifications, etc.), and therefore the actual vessel weight was questionable.

DETAILED Analysis:

With a lightship weight of approximately 212 ltons (assumed based upon LCU-1646 class lightship weight), plus an "assumed" variable load of approximately 40 ltons, it was estimated that approxi-



Ship Characteristics			
LBP:	134 ft	**Cb:**	0.63
Beam:	29.06 ft	**Cw:**	0.79
Depth:	8 ft	**Cp:**	0.62
Service Speed:	12 kts	**Cm:**	0.98
Disp. (Lightship):	212 LTons	**MT1:**	51 ft-Lton/in
Draft (Lightship):	3.2 ft	**TP1:**	7.1 ft-Lton/in

General Information

Salvage Engineer: *LCDR Jeff Stettler*
Phone: *(703) 607-2758*
Casualty Type: *Sinking*
Location: *NAVSTA Roosevelt Roads, PR*
Ship Name/Class: *YFU-83*
Owner: *NAVSTA Roosevelt Roads,* PR
Flag: *U.S.*

Organization: *NAVSEA 00C/SUPSALV*
Email: *stettlerjw@navsea.navy.mil*
Casualty Date: *September '98*
Customer: *MDSU 2*
Ship Type: *YFU*

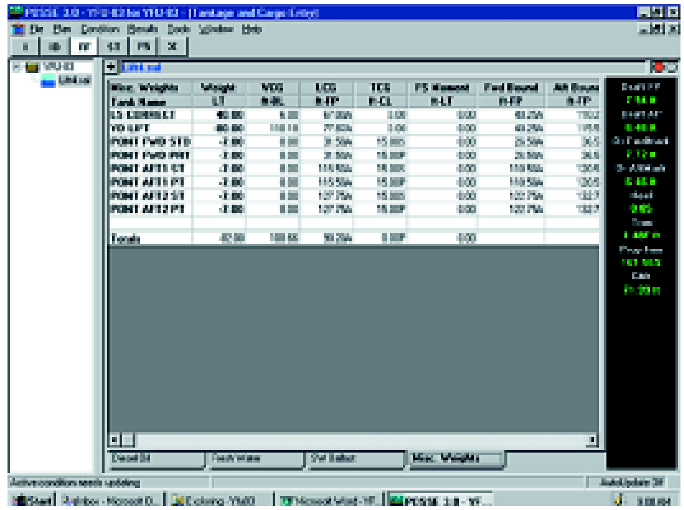
mately 250 ltons of buoyant force would have to be obtained. Actually, accounting for lost buoyancy of the superstructure, more than 250 ltons would be required than to get the "decks awash".

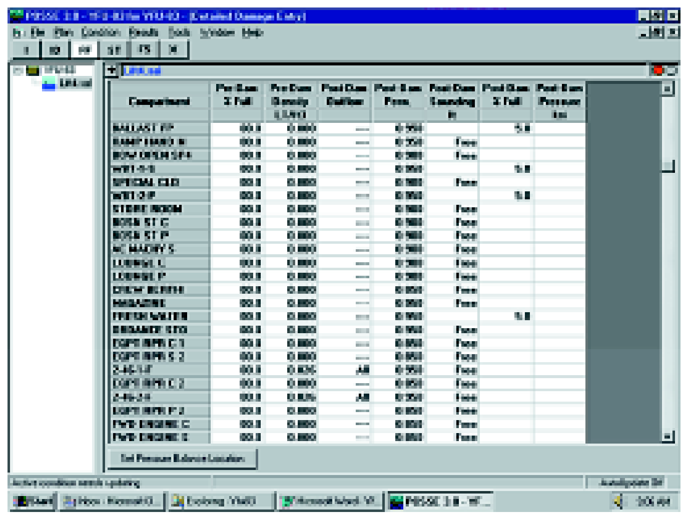
The MDSU2's plan involved a combination of the following elements:

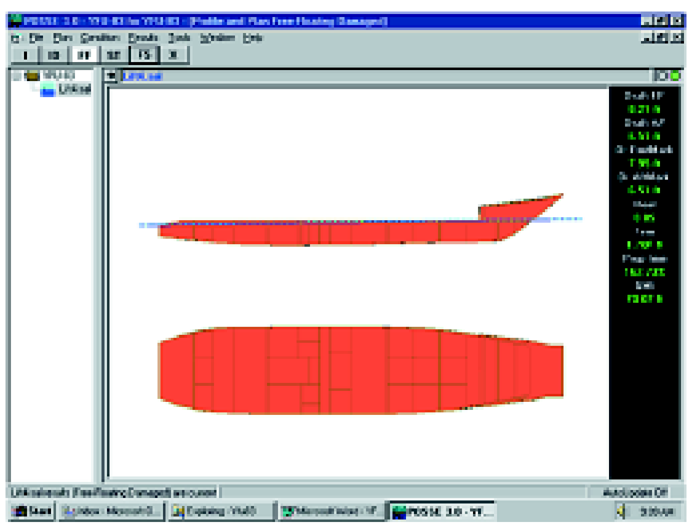
- Direct lift with NAVSTA Roosevelt Road's YD-251 (with a 100 short ton lift capacity), using a 4-part lifting sling attached to 4 existing lifting padeyes on the YFU.
- External buoyancy supplied by six 8.4 long ton salvage pontoons, from the ESSM base in Williamsburg, VA. Pontoons were secured by running 1-inch wires under the YFU, requiring limited jetting under the hull.
- Internal buoyancy gained through residual air in a number of internal compartments (ballast tanks, fresh water tank). Existence of this residual air was confirmed during salvage survey dives by manual sounding. An additional void space was initially believed to be empty, but was discovered to be full during the lifting process.
- As margin (to provide extra buoyancy if required), two compartments were rigged with compressed air lines and standpipes to permit (partial) dewatering. Some air was introduced into the Equipment & Repair Parts Storeroom (midships) and Anchor Winch Compartment during the lifting process.

With this basic plan, POSSE was used to estimate drafts with the vessel lifted to the surface. Lifting force provided by the YD-251 was applied as a "Misc. Weight" (negative weight). The location of the YD lift force was specified to match the actual position of the hook in the ship's coordinate system (i.e. based on geometry of the padeye locations and lifting sling lengths). Lifting forces provided by the salvage pontoons were likewise specified as negative "Misc. Weights", located based upon pontoon placement. It was recognized that the YD-251 and the salvage pontoons would probably not provide full design lifting capacity, and therefore they were derated appropriately.

For the "free floating" damaged con-







dition, all compartments were damaged (flooded). Dewatered compartments were accounted for by specifying a "Post-damaged % full". To be conservative and account for some free surface of residual water, dewatered compartments were assumed to have 5% remaining.

Based on the above condition, drafts were calculated to be 8.21' forward and 6.51' aft, with a heel of 1 degrees to starboard. With air applied to the Equipment & Repair Parts Storeroom (midships) and Anchor Winch Compartment (assumed 50% full), drafts were calculated to be 8.17' forward and 5.14' aft, with a heel of 0.8 degrees starboard.

Special Considerations / Lessons Learned

This was a fairly simplified application of POSSE for "heavy lift salvage". The main intent was to attempt to provide prediction of required lifting forces (external and internal) to sufficiently lift the vessel to the surface (with suitable trim and heel) for dewatering using submersible pumps.

The main difficulty from a POSSE perspective was in obtaining reasonable estimates of the ship's actual weight as it sat on the bottom. It was necessary to build in sufficient margin to the lifting forces to get the job done.

About POSSE Technotes

POSSE Technotes are written and distributed to provide basic overview and lessons learned of POSSE applications for actual salvage engineering evaluations. POSSE Technotes are distributed by NAVSEA 00C to all POSSE users, as well as Engineering Duty Diving and Salvage Officers, and other selected organizations and individuals.

Articles, letters, queries, and comments should be directed to the Commander, Naval Sea Systems Command, NAVSEA 00C, 2531 Jefferson Davis Highway, Arlinton, VA 22242-5160. (Attn: POSSE Technotes). Visit our website at **http://www.navsea.navy.mil/sea00c**.

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